RESEARCH DEPARTMENT

Visit to School of Radiometeorology, Lagonissi, Greece

September 1964

VISIT REPORT No. A-088

1964/66

THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION

RESEARCH DEPARTMENT

SCHOOL OF RADIOMETEOROLOGY, LAGONISSI, GREECE, SEPTEMBER 1964

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1. INTRODUCTION

The School of Radiometeorology, attended by the author, was held at Lagonissi, Greece from the 31st August to 11th September 1964. It was organized by the Centre National d'Études des Télécommunications of France, under the auspices of NATO, and was attended by about 30 students of post-graduate level from West European countries within the NATO bloc. The students included both radio engineers interested in the effect of the atmosphere on radio wave propagation and meteorologists interested in radio techniques for studying the Earth's atmosphere. The lecturers were drawn mainly from Universities and Institutes in Western Europe and included representatives of the Radio Research Station at Slough, together with Dr. Smith-Rose, a Past President of U.R.S.I. The School was officially opened by the Greek Minister of Posts and Telecommunications.

The subject studied concerns the propagation of metric and decimetric waves, whose paths may be divided into three regions. In the first, which extends up to the horizon, the rate of attenuation is comparable with that which the wave would have in free space. Beyond the horizon the field strength falls rapidly by about 80 dB; in this region its value obeys the laws of diffraction. In the third region, however, the rate at which the field strength falls is less rapid because here refraction around the surface of the Earth predominates over diffraction. In this region, however, the field strength is subject to large fluctuations which depend on the weather, because meteorological factors such as temperature, pressure and humidity affect the dielectric constant of the medium surrounding the Earth. The resulting variations in the dielectric constant (and therefore the refractive index) of the atmosphere cause radio waves to deviate from a straight path and under certain circumstances abnormal propagation around the curvature of the Earth becomes possible.

The refractive index n differs from unity by only a few parts in a million and it is therefore customary to express it in the form

$$n = 1 + N \times 10^{-6}$$

In a stable or "standard" atmosphere, N has a value of approximately 300 at sea level and decreases, initially uniformly with height, at the rate of 39 units per kilometre. Under such circumstances a radio wave is refracted around the surface of the Earth along a path whose radius of curvature is somewhat greater than that of the Earth*. Under certain meteorological conditions refractive index gradients much greater than 39 may occur. The radius of curvature of the ray may then be equal to, or even less than, that of the Earth; it is under these circumstances that abnormal propagation occurs.

Although the papers presented were mainly concerned with the mechanisms which cause refractive index variations, their measurement by radio methods and their effect on radio-wave propagation, attention was also paid to the absorption of radio waves by the Earth's atmosphere.

2. THE MEASUREMENT OF REFRACTIVE INDEX VARIATIONS

An account was given of the work which is being performed by the Radio Research Station at Slough on the measurement of refractive index by means of airborne microwave refractometers. These measurements have shown[1] that sudden discontinuities in refractive index commonly occur at heights up to 3 km and appear to extend over considerable horizontal distances. Simultaneous soundings with vertical incidence radar have shown that reflexions may be caused by these discontinuities; reflexions are not, however, always observed because the amplitude of a reflected signal must depend on the detailed profile of a discontinuity. When reflexions are observed, however, they are always found to be associated with refractive index variations. Recent work in which the fine detail of the variations was investigated by means of refractometers spaced both vertically and horizontally was described; for refractometers spaced 1 m it has been found that there appears to be no significant difference between

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* The Earth immersed in a standard atmosphere is often regarded as equivalent to a sphere, having a radius 4/3 times the true radius of the Earth, immersed in a medium of unit refractive index, i.e. vacuo. This concept is particularly convenient when considering the diffraction of waves over obstacles.

the mean horizontal and vertical variations. These measurements indicate that large refractive index gradients are accompanied by smaller variations, probably caused by turbulence, which are distributed isotropically.

3. SCATTERING DUE TO TURBULENCE

Small variations in refractive index due to turbulence in the atmosphere can cause an incident wave to be partially scattered and this mechanism can result in enhanced propagation of waves around the curvature of the Earth. This effect is being studied theoretically by assuming that a turbulent atmosphere can be represented by an infinite set of standing waves of air pressure*. Each component wave is thus a sinusoidal stratification of the atmosphere having arbitrary wavelength and orientation. For a given propagation path only those components whose orientation is such that they behave as plane mirrors can contribute significantly to the scattered wave. Experiments were described in which attempts were made to determine the wavelengths of these components, by measuring the power scattered from a common volume of the atmosphere illuminated by two directional aerials, one of which is connected to a transmitter and the other to a receiver. To obtain useful results the measurements should ideally be performed over a wide range of frequencies; this however was not practicable with the equipment described, which operated on a fixed frequency of 6010 Mc/s. Instead, experiments were performed in which the angles of elevation of the aerials were varied in order to see how the apparent turbulence of the atmosphere varies with height and position.

If the experimental limitations can be overcome this method of exploring the structure of the atmosphere would appear to offer interesting possibilities. The application of the results of such an investigation to the prediction of the degree of scattering, and therefore of abnormal propagation, which might be experienced under different weather conditions, might then be feasible. It seems unlikely however that such a method of prediction will be developed in the immediate future.

4. PROPAGATION DUE TO DUCTING

If an increased refractive index gradient occurs in an elevated layer of the atmosphere a wave entering the layer from below may be refracted back towards the Earth and travel to a point some distance beyond the horizon. If the amount of refraction is insufficient to return the

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* These are not standing waves in the acoustic sense but small sinusoidal variations in the static air pressure.

wave to the Earth, however, the wave will re-enter the layer at a point further on and the refraction process will be repeated. Under these conditions a wave can, in theory, travel to a considerable distance*.

For this process, known as ducting, to occur the refractive index gradient in the layer or duct must exceed the value which causes the radius of curvature of a ray to equal that of the Earth. The ray must also enter the duct almost at grazing incidence or it will penetrate the duct and be lost. For long distance propagation to occur the duct must exist over a large area; this requires stable meteorological conditions over level terrain or the sea.

Research into the formation of ducts which is being carried out at the University of Hamburg was described. Experiments are being performed over a sea path of 80 km between Heligoland and the mainland, using frequencies in the range 160 Mc/s to 7 Gc/s. These experiments clearly show the formation of ducts under idealized conditions, field strengths slightly greater than the free space value being occasionally observed as a result of focussing. However only partial correlation between theory based on meteorological factors and measured field strengths was reported.

Experiments are also being carried out near Hamburg on overland propagation, using a frequency of 500 Mc/s. These measurements do not form part of the data utilized by the C.C.I.R., but the measured field strengths show good general agreement with the C.C.I.R. values. Detailed information concerning fading rates and correlation with meteorological parameters are contained in a paper which was not, however, presented at Lagonissi. A copy of this paper has been promised.

5. REDUCTION OF EFFECTIVE AERIAL GAIN DUE TO ATMOSPHERIC TURBULENCE

If the size, and therefore the gain, of an aerial connected to a transmitter is increased, the actual increase in signal strength measured beyond the horizon may be somewhat less than the true increase in aerial gain. This effect is due to the fact that the contributions to the distant field from all parts of the aerial are not fully correlated; the correlation becomes poorer as the size of the aerial increases. The amount by which the apparent gain of an aerial falls below its true gain therefore increases with the size of the aerial.

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* A similar process sometimes occurs in ionospheric propagation, giving rise to multiple round-the-world echoes.

A comprehensive paper[2] on the subject summarized measurements carried out by a number of workers and presented the results of recent measurements, in which signals transmitted between parabolic aerials of different sizes were compared. Although the majority of these measurements have been performed in the 2 - 4 Gc/s range, a few measurements made at lower frequencies (400 - 900 Mc/s) agree reasonably well with those carried out at higher frequencies. The gain reductions measured appear to be independent of distance, at least in the range 150 - 500 km.

The results of the measurements suggest that the apparent gain of a 40λ linear aerial may be 2 dB less than its true gain so far as propagation beyond the horizon is concerned. This result, which can be derived from measured reductions of the effective areas of parabolic dishes, is based on the assumption that it applies regardless of the orientation of the linear aerial. This assumption may not be true, however, and the figure quoted may not be correct for a verticallinear aerial. In view of this, and of the small number of measurements which have been made at the frequencies used for broadcasting, further investigation with linear aerials might be worthwhile. A consequence of the effect is that, if predictions of distant field strengths are based on propagation curves derived from measurements made with low-gain transmitting aerials, the predicted values will be too high when the transmitting aerial has a high gain. Conversely, propagation curves derived from measurements made with high-gain transmitting aerials will give distant field strengths which are too low if low-gain aerials are used. The effect could therefore cause a small error in predictions of co-channel interference levels.

6. ABSORPTION OF MILLIMETRE WAVES

Molecular resonances can give rise to absorption but the frequencies at which these resonances occur are of the order of 50 Gc/s; their effects are therefore insignificant at the frequencies used for broadcasting. The only constituent of the atmosphere which exhibits this resonance effect is the oxygen molecule; it has a number of resonant frequencies corresponding to different quantized energy levels. The amount of absorption depends on air pressure and temperature and is modified by the Earth's magnetic field and the polarization of the incident wave. Absorption can also be caused by rain and snow but, again, these effects are negligible at frequencies below 1000 Mc/s.

7. CONCLUSIONS

So far as broadcasting is concerned, the science of radiometeorology concerns the effect of climatic conditions on the propagation of v.h.f. and u.h.f. waves to distances beyond the horizon. Its study is therefore relevant when co-channel interference problems are being considered. Despite the amount of research which is being carried out there is as yet little agreement between measured field strengths and values predicted from meteorological factors. For predicting co-channel interference levels, therefore, there appears to be at present no satisfactory alternative to the use of propagation curves, such as those published by the C.C.I.R.[3], which are based on statistical analyses of measured field strengths. A slight modification to these curves to take into account variations of transmitting aerial gain might be desirable, although the evidence at present available suggests that this correction is relatively small.

8. REFERENCES

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